Performance Analysis Rim Driven Propeller as a Propulsor using Open Water Test.

Agoes Santoso[1], Irfan Syarif Arief[2], Anggara Tio Kurniawan[3]

***Abstract*—the use of duct in propeller is one of the breakthrough in the development of the propeller. Ducting not only claimed toincrease the efficiency of the propeller, but also capable to protect the propeller from impact therefore propeller's lifespan is longer. From that idea then RDP is created. RDP propeller blades are designed to be fixed at their housing called Rim, in the other word, the driving force came from its rim. Nowadays, the usage of non-conventional RDP blade is more common in practice. This research will discuss about design analysis of Kaplan Propeller Kaplan Ka-70 that modified on its thickness distribution. This researchusing motorload as variable. The simulation using Open Water Test. The result, highest value of KT and KQ occur on 30% motor load and highest efficiency is 18,338% achieved on 260 Rpm.**

Keywords—Kaplan, Ka-70, RDP, Open Water Test,Propeller

I. INTRODUCTION

Application of duct around propeller is widely used because the ducting gives better efficiency and protects the propeller from physical damage [1], until Rim Driven Propeller (RDP) being introduced at USSR Valery Chalov and Rodina [2]. RDP propeller blades are connected to the rim, instead of the hub. It is possible for RDP to be well functioned even without a hub. RDP has several advantages: (1) reduce the head loss pressure and increase the uniformity of water flow, (2) Less noise and vibration, (3) Lower cable entrapment risk because there is no shaft, (4) No energy losses which caused by the gap between the blade and rim. Because of those advantages, in this research researcher wants to understand the performance of the RDP by sking this question.

1) How is the performance of designed RDP?
2) What is the speed of RDP rotation until it reaches the desired thrust?

The important point to be discussed in this paper is to know performance shown by the RDP. The design of propeller using Kaplan Ka-70 blade. Then the propeller would be modified with reverse thickness distribution because the shaft removed and the blades are connected to the duct.

II. LITERATURE REVIEW

Propeller, actually is a rotating tool which produce thrust to move certain objects such as Aircraft, Ships,orBoats [3], Propeller can be divided into several types depending how it works, blade shape, or propeller for special design of boat. Duct which surrounded propeller been used commercially. Propellers are generally placed in the lowest possible place at the aft of the ship. Propeller must have a center line (diameter). As a quick and rough estimates, the center line of the propeller must be less than two-thirds of Ship Draught given by:

$$D_{maks} = \frac{2}{3}T_A \qquad (1)$$

Thrust produce by propeller is a very important component, which is used to overcome Resistance or hindering ship. On ideal condition, the amount of thrust that drag is happening onboard. However, these conditions are very unrealistic, because in fact in the hull of the ship occur hydrodynamic phenomena which cause degradation of the value of the thrustamountto the ship. So thrust of the ship can be written as a model equation, as follows [4];

$$T = \frac{R}{(1-t)}; \qquad (2)$$

$$R_T = where\ 0{,}5 \times \rho \times C_T \times S = \alpha$$

$$R_T = \alpha \times V_s^2 ; \qquad (3)$$

Then known formula to determine the value Thrust (T), wake factor (w) and service speed (Vs)

$$(Vs) = 0{,}5 \times \rho \times C_T \times S \times V_s^2 \qquad (4)$$

$$T = \frac{V_a}{(1-t)} \qquad (5)$$

$$w = 1 - \frac{V_a}{V_s} \qquad (6)$$

$$V_s = \frac{Va}{(1-t)} \qquad (7)$$

Bysubtituting it (3) and (5) to (7)

$$V_{SHIP} = \frac{\alpha \times V_A^2}{(1-t)(1-w)^2} \qquad (8)$$

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Advance coefficient (J)

$$J = \frac{V_A}{n \times D} \quad (9)$$

$$\eta_0 = \frac{J \times K_T}{2\pi \times K_Q} \quad (10)$$

Where :
KT = Coefficient of thrust propeller.
KQ = Coefficient of torque propeller.
J = Coefficient of advanced propeller
Va = Velocity advanced.
D = Diameter Propeller.
n = Round Propeller.
T = Thrust Propeller.
Q = Torque Propeller.
ρ = FluidDensity

Thrust and Torquecan be calculated as follows

$$T_{prop} = K_T \, \rho \, n^2 D^4 \quad (11)$$

$$Q_{prop} = K_Q \, \rho \, n^2 D^5 \quad (12)$$

Rim Driven Propeller is a propulsor whose center of motion does not originate from the center point of the axle but its movement comes from its duct. So tip of the propeller blade attached to the duct part (Baoet all, 2015). There is even a RDP type that does not have a hub so that the disturbance caused by objects in water can not get caught in the propeller blades.
RDP has been discovered and used since the mid-20th century in Germany (Lebedev, 1969) on the ship Valery Chkalov and Soviet-owned Rodina. In its development, RDP is used as a Thruster. So its name also changed to RIM Driven Thruster. At this time where electric motor technology is advance, RDT is also commonly used [3].RDP and RDT have been developed by several companies in the world such as Voith (Germany), Brunvoll (Norway) and Van der Velden (Netherlands) [6].The analysis of the designed propeller is using Open Water Test. Open water test carried out on ship model basin or towing tank. There are several types of tests that can be done here, the model can be drawn on a straight line or a circular path, and can also be swayed to model the ship when the ship is exposed to waves at sea. The style that appears on the ship model is measured using a dynamometer. Test can be used to evaluate the design as a whole, or just focus on the characteristics of the propeller. Open Water Test is one method that focuses on the characteristics of propeller as mentioned above.To solve the problem in this research will be made prototype to be simulated with open water test method.

III. RESEARCH METHODS

To solve the problem in this research researcher will make prototype to be simulated with open water test method.
The step researcher take is:
1. Problem Identification
2. Study of literature
3. Collecting Data
4. Design Prototype of Propeller
5. Simulation
6. Data analysis and Discussion
7. Conclusion and Recommendation

IV. ANALYSIS AND DISCUSSION

This research uses Kaplan propeller type in the process. The Kaplan type is chosen because the outer diameter forms a circle so that the outermost portion of the propeller can be modified by plugging it into the Duct. The propeller shape has also been modified in the thickness distribution. In general the propeller blade is thicker at the center of the propeller, but since the blade of the RDP propeller is attached on the outer part, the thickness distribution is reversed so that the outer part of the blade is thicker than the center of the propeller. Here is the data propeller to be modeled.

TABLE 1
PROPELLER SPESIFICATION

Type	Kaplan Ka-70
Diameter	0,2 m
EAR	0,7
Hub D	0,2 D
Pitch	35^o

Process of making Prototype on this research is done by using CNC 4 axis machine owned by Centre of science and research control and system. The use of CNC machines is intended to make sure shape of the bladeis made accurately with the geometry that has been designed. Before the machine can make a blade shape, the CNC machine needs to receive data input in .STL, .IGES, .IPT or any other formats.The blade propeller model that has been created is simulated using MasterCAM software.

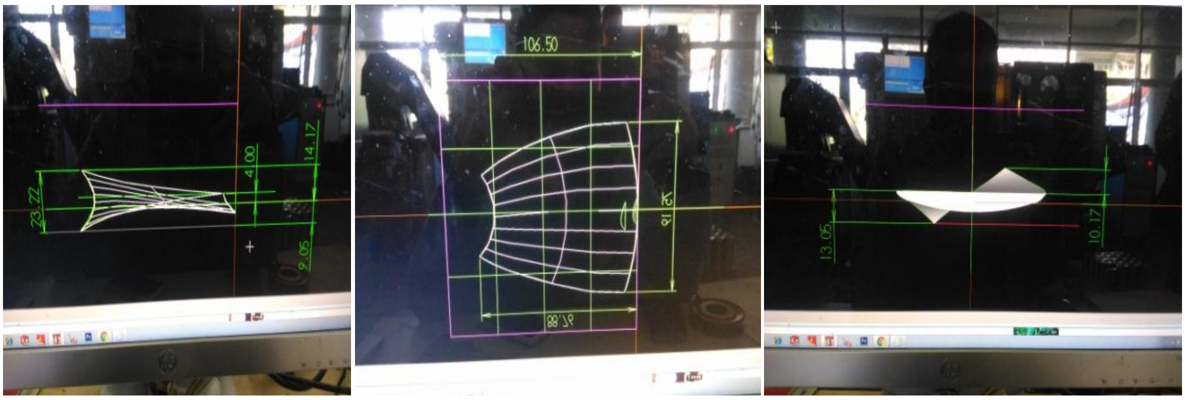

Figure 1 Blade design seen from various angle, side (left), front (middle), and top (right)

Figure 2 blade making process, under CNC machine (left), Result of CNC (Middle), and propeller after got cut from its base (right)

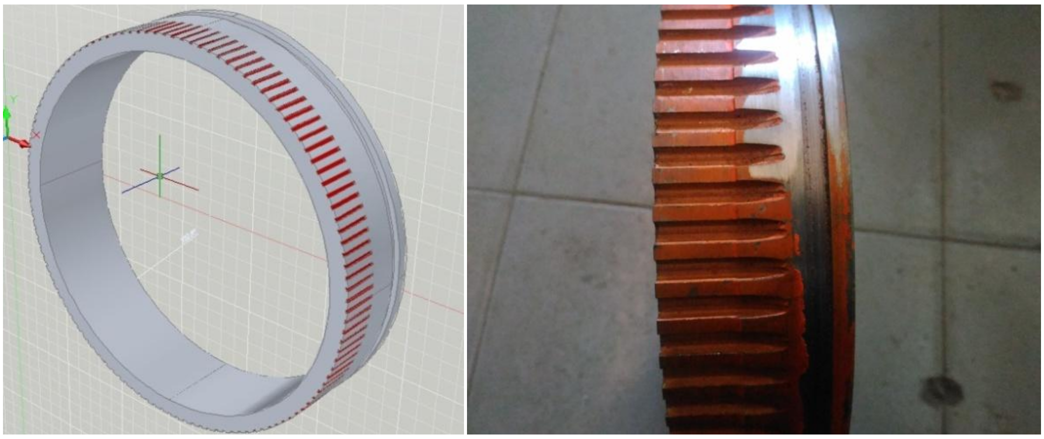

Figure 3 Design of Rim for RDP in 3D (left) and real (right)

The data obtained from the simulation process will also be used as validation with the actual CNC process.For ducting propeller modeling, since for RDP there is no definite data with respect to the specific duct form for RDP then this research compares and modifies the ducting form of an existing journal that is the work of Alexey Yu. Yakovlev, Marat A. Sokolov, Nikolay V. Marinich entitled "Numerical Design and Experimental Verification of a RIM-Driven Thruster" and Krisnoyya, Abadi's work [7].

After going through the stages in the test propeller, then obtained the results of flow velocity. Based on the test results then obtained the data as presented in Table 2 and Table 3.

Figure 4 Designed Frame seen from front (left) and side (right)

TABLE 2
DATA COLLECTING RESULT RDP (VA)

Type	Load Motor	Rpm Motor	Rpm Propeller	Rps Propeller	Va (m/s)
Advance RDP Ka3 70	30%	230	115	1,92	0,126
Advance RDP Ka3 70	35%	290	145	2,42	0,256
Advance RDP Ka3 70	40%	330	165	2,75	0,286
Advance RDP Ka3 70	45%	380	190	3,17	0,324
Advance RDP Ka3 70	50%	430	215	3,58	0,407
Advance RDP Ka3 70	55%	470	235	3,92	0,456
Advance RDP Ka3 70	60%	520	260	4,33	0,524
Advance RDP Ka3 70	65%	560	280	4,67	0,596
Advance RDP Ka3 70	70%	610	305	5,08	0,604
Advance RDP Ka3 70	75%	665	332,5	5,54	0,637

From this experiment also take data in the form of Thrust, but because the accuracy of the tool is less so it is difficult to retrieve data on the variation of small value, so for data thrust data retrieval, the data is taken with a difference of value of 15% each step.

TABLE 3
DATA COLLECTING RESULT RDP (*THRUST*AND*TORQUE*)

Load Motor	Type	Rpm Propeller	Thrust (N)	Torque (Nm)
30%	Advance RDP Ka3 70	115	8	0,84
45%	Advance RDP Ka3 70	190	11	1,155
60%	Advance RDP Ka3 70	260	19	1,995
75%	Advance RDP Ka3 70	333	30	3,15

From the test results can be used to determine the KQ and KT values of each rotation condition using equation (11) as follows.

$$K_Q = \frac{Q_{Prop}}{\rho \times n^2 \times D^5} \quad (11)$$

Where Q is the Torque of Propeller and KQ is the Coefficient of Torque. Then to get the value of KT calculated using equation (12) as follows.

$$K_T = \frac{T_{Prop}}{\rho \times n^2 \times D^4} \quad (12)$$

Where T is the thrust force of the propeller and KT is the coefficient of doron force. From the formula will get the results of KT and KQ figures in accordance with the blur rotation. Here are the results of KQ and KT calculations. Then from the value of KT and KQ we can calculate the efficiency using equation (10) as follows.

$$\eta = \frac{J \times K_T}{2\pi \times K_Q} \quad (10)$$

After the calculation then the result of each value of J can be seen in Table 4.

TABLE4
CALCULATION RESULT OF J, KT, AND 10 KQ

No.	Type	Load Motor	Rpm Propeller	Rps Propeller	Va (m/s)	KT	10KQ	J	eff
1	advance RDP Ka3 70	30%	115	1,92	0,126	1,356	7,121	0,329	9,970%
2	advance RDP Ka3 70	45%	190	3,17	0,324	0,684	3,592	0,512	15,516%
3	advance RDP Ka3 70	60%	260	4,33	0,524	0,633	3,325	0,605	18,338%
4	advance RDP Ka3 70	75%	332,5	5,54	0,637	0,611	3,207	0,575	17,432%

Here will be a discussion of the results of data processing from the previous sections. The first thing to be discussed is the comparison between Torque and Load motors.

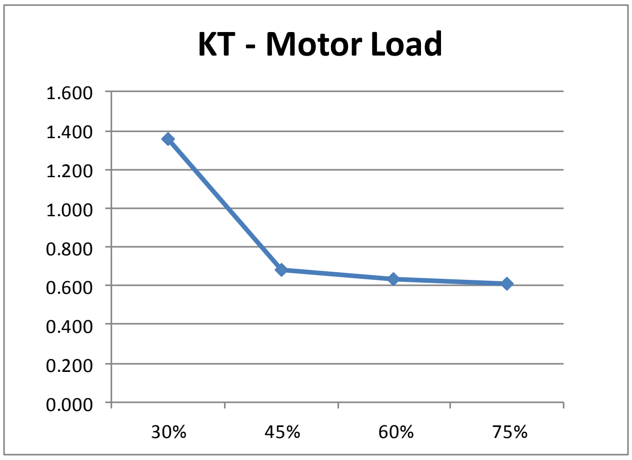

Figure 5 RDP KT-Motor Load Chart

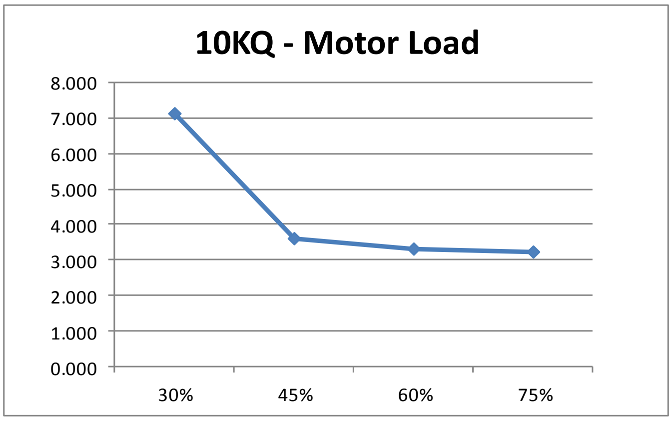

Figure 6 RDP 10KQ-Motor Load Chart

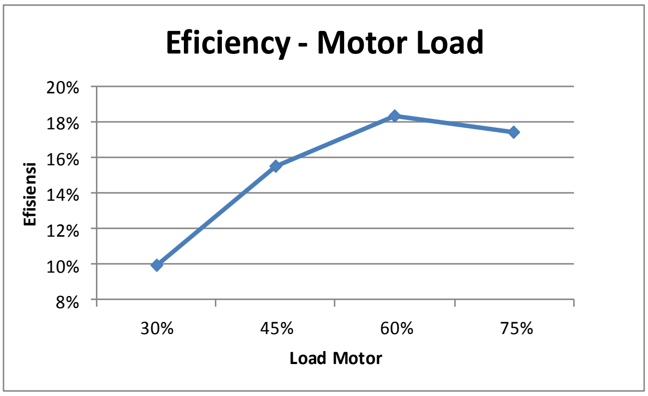

Figure 7 RDP Efficiency-Motor Load Chart

In the graph above Figure 5 can be seen that with the increasing load motor so KT numbers will decrease. This is because each motor load value rises, means the rpm of the propeller also increases, and the KT function is inversely proportional to the rotation of the second motor. This has an impact on the declining value of KT as the percentage of motor load increases. And obtained the highest KT value at 30% motor load (115 Rpm) which is worth 1.356

In the graph above (Figure 6) can be seen that with the increasing load motor so the number 10KQ will decrease. This is because each load value of the motor rises, means the rpm of the propeller also rises, and the 10KQ function is inversely proportional to the rotation of the second motor. This has an impact on the declining

Value of 10KQ along with the increasing percentage of motor load. And obtained the highest 10KQ value at 30% motor load (115 Rpm) which is worth 7,121
In Efficiency-Motor Load Chart (Figure 7) above, it can be seen that the efficiency increases with increasing motor load. However, in percentage of motor load 60% - 75% the value of its efficiency began to fall. This disebbkan on motor load between 60% - 75% KQ and KT numbers are not far adrift, This has a close relationship with the formula of efficiency (10). Where the rate of efficiency depends also on the KQ, KT, and J figures so that the efficiency graph - Load motor shaped like picture 4.7.3. Peak efficiency is achieved when the Load motor is 60% (260 rpm) with a value of 18.338%.

V.CONCLUSIONS AND SUGGESTIONS

Based on simulation result which have been done can be concluded that:

The highest thrust and torque value is reached at 333 rpm which is thrust value 30 N and torque value 3,15 Nm.

In the analysis of 10 KQ and KT, the highest value is achieved at propeller round 115 Rpm that is 10 KQ is equal to 7,121 and KT value is equal to 1,356.

In the efficiency analysis, the highest efficiency experienced by RDP when the propeller rotates at a speed of 260 Rpm, the value achieved is 18.338%.

Based on the results of simulation and data processing done, there are still some shortcomings in the writing of this research. For the sake of obtaining more accurate data, the authors suggest the following:

1. Need to be optimized frame shape so that thrust and torque propeller is not deviated by factor From outside of propeller.
2. Need to be re-tested with more adequate equipment and with appropriate regulations.
3. Need to do comparison for propeller with different hub and / or pitch angle.
4. Need to do comparison for propeller with different material.
5. Need to do comparison with the propeller without change in the thickness distribution, but need to do the calculation of previous strength.
6. Need to be tested with equipment more adequate so that data obtained data more accurate.
7. Need to be optimized at the top of the blade (middle propeller).

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